Status of the HDMS experiment, the GENIUS project and the GENIUS-TF

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Abstract. The status of dark matter search in Heidelberg is reviewed. After one year of running the HDMS prototype experiment in the Gran Sasso Underground Laboratory, the inner crystal of the detector has been replaced with a HPGe crystal of enriched ^{73}Ge. The results of the operation of the HDMS prototype detector are discussed. In the light of the contradictive results from the CDMS and DAMA experiments the GENIUS-TF, a new experimental setup is proposed. The GENIUS-TF could probe the DAMA evidence region using the WIMP nucleus recoil signal and WIMP annual modulation signature simulataneously. Besides that it can prove some key parameters of the detector technique, to be implemented into the GENIUS setup and will in this sense be a first step towards the realization of the GENIUS experiment.

1 Introduction

The topic of Dark Matter search has lately gained some actuality by the results of the DAMA [1] and CDMS [2] experiments. The DAMA collaboration claims to see positive evidence for WIMP dark matter using the annual modulation signature, whereas the CDMS experiment almost fully excludes the DAMA allowed cross-sections for WIMP dark matter (the 3 σ region with 84% C.L.). It is therefore of utmost importance to independently test these results using both experimental approaches: to look for the WIMP-nucleus recoil signal and for the annual modulation effect. However, should the positive DAMA WIMP evidence be disproven, a large step forward in terms of increasing the sensitivity of Dark Matter experiment is needed in order to obtain relevant data concerning WIMP dark matter.

   Here we present first results of the Heidelberg Dark Matter Search (HDMS) experiment [3,4], which took data over a period of about 15 months in the Gran Sasso Underground Laboratory at LNGS in Italy. After a description of the experimental setup, the performance of the detectors is discussed. The last 49 d of data taking are then analyzed in terms of WIMP-nucleon cross sections and a comparison to other running dark matter experiments is made.

   In the following section we introduce the GENIUS-TF [5,6], a new experimental setup to probe the evidence region favoured by the DAMA experiment [1] and to test the prerequisites neccessary to realize the Genius project [7,8].

[⋆] talk presented by B. Majorovits

2   The HDMS experiment

HDMS operates two ionization HPGe detectors in a unique configuration [4]. A small, p-type Ge crystal is surrounded by a well-type Ge crystal, both being mounted into a common cryostat system (see Figure 1 for a schematic view). To shield leakage currents on the surfaces, a 1 mm thin vespel insulator is placed between them. Two effects are expected to reduce the background of the inner target detector with respect to our best measurements with the Heidelberg-Moscow experiment [9]. First, the anticoincidence between the two detectors acts as an effective suppression of multiple scattered photons. Second, we know that the main radioactive background of Ge detectors comes from materials situated in the immediate vicinity of the crystals. In the case of HDMS the inner detector is surrounded (apart from the thin isolation) by a second Ge crystal - one of the radio-purest known materials.
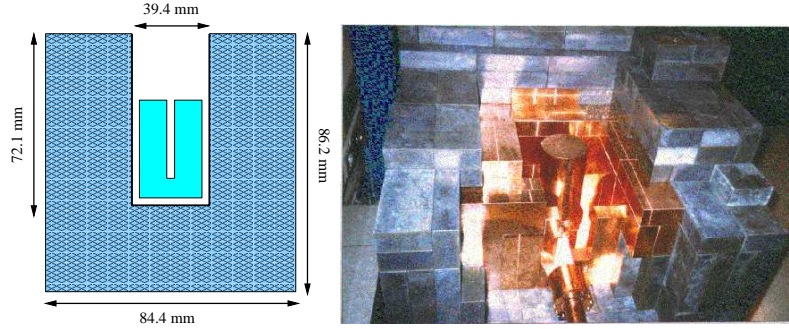

Fig. 1. Left: Schematic view of the HDMS experiment. A small Ge crystal is surrounded by a well type Ge-crystal, the anti-coincidence between them is used to suppress background created by external photons. Right: The HDMS detector during its installation at LNGS.

In order to house both Ge crystals and to establish the two high voltage and two signal contacts, a special design of the copper crystal holder system was required. The cryostat system was built in Heidelberg and made of low radioactivity copper, all surfaces being electro-polished. The FETs are placed 20 cm away from the crystals, their effect on the background is minimized by a small solid angle for viewing the crystals and by 10 cm of copper shield.

2.1   Detector Performance at LNGS

The HDMS prototype was installed at LNGS in March 1998. Figure 1 shows the detector in its open shield. The inner shield is made of 10 cm of electrolytic copper, the outer one of 20 cm of Boliden lead. The whole setup is enclosed in an air tight steel box and flushed with gaseous nitrogen in order to suppress radon diffusion from the environment. Finally a 15 cm thick borated polyethylene shield

surrounds the steel box in order to minimize the influence of neutrons from the natural radioactivity and muon produced neutrons in the Gran Sasso rock.

The prototype detector successfully took data over a period of about 15 month, until July 1999. The individual runs were about 0.9 d long. Each day the experiment was checked and parameters like leakage current of the detectors, nitrogen flux, overall trigger rate and count rate of each detector were checked. The experiment was calibrated weekly with a ^{133}Ba and a ^{152}Eu-^{228}Th source. The energy resolution of both detectors (1.2 keV at 300 keV inner detector and 3.2 keV at 300 keV outer detector) were stable as a function of time. The zero energy resolution is 0.94 keV for the inner detector and 3.3 keV for the outer one.

The energy thresholds are 2.0 keV and 7.5 keV for the inner and outer detector, respectively.

Due to the very special detector design, we see a cross-talk between the two detectors. The observed correlation is linear and can be corrected for off-line [10]. After correction for the cross talk and recalibration to standard calibration values, the spectra of the daily runs were summed. Figure 2 shows the sum spectra for the outer and inner detector, respectively (the most important identified lines are labeled).
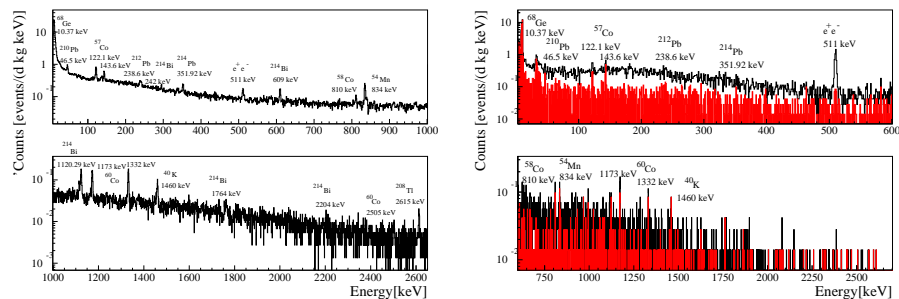

Fig. 2. Left: Sum spectrum of the outer detector after a measuring time of 363 days. The most prominent lines are labeled. Right: Sum spectrum of the inner detector after a measuring time of 363 days. The most prominent lines are labeled. The filled histogram is the spectrum after the anti-coincidence with the outer detector.

In the outer detector lines of some cosmogenic and anthropogenic isotopes, the U/Th natural decay chains and ^{40}K are clearly identified. The statistics in the inner detector is not as good, however the X-ray at 10.37 keV resulting from the decay of ^{68}Ge, some other cosmogenic isotopes, ^{210}Pb and ^{40}K can be seen. The region below 10 keV is dominated by the X-rays from cosmogenic radio nuclides. In addition a structure centered at 32 keV is identified. Its origin has recently been understood to be due to an artefact of the special detector configuration.
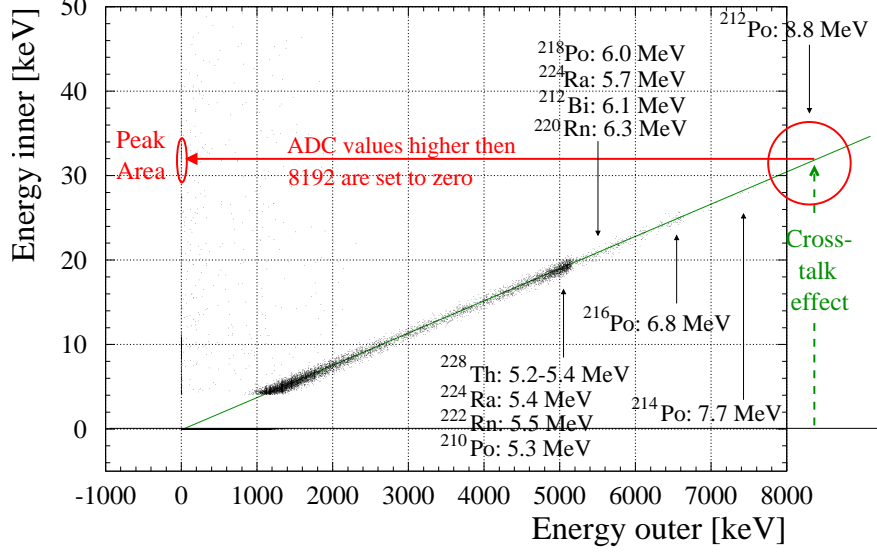
Fig. 3. Origin of the structure observed at 32 keV in the inner detector: Shown is a scatter plot of all events with energies less then 50 keV in the inner detector. Each dot corresponds to one event. The position on the y-axis corresponds to the recorded energy in the inner detector, while the position on the x-axis displays the recorded energy in the outer detector. The linear dependence of the pick-up in the inner detector due to the energy deposition in the outer detector is nicely seen. Clearly visible are regions dominated by α-particles due to the decay chains of ^{238}U and ^{232}Th. The highest energetic α-particles resulting from these decay chains stem from ^{212}Po with 8.8 MeV. Due to the limited dynamic range of the ADCs an event with such high energy can not be stored in the memory and is thus set to zero. Like this the event only appears with its crosstalk signal of $\sim$32.5 keV in the inner detector, faking a peak, which is not affected by the anticoincidence.

In Fig. 3 a scatter plot of all events with energy depositions less then 50 keV in the inner detector is shown. The linear dependence of the pick-up signal in the inner detector from the energy deposition in the outer detector is nicely seen. The largest fraction of events with energies above 3 MeV in the outer detector do result from α contaminations. These stem from the decay-chains of ^{238}U and ^{232}Th, most probably resulting from U/Th contaminations being present in the soldering tin of the contacts for the outer detector. The highest energetic α-decays with 8.8 MeV result from the decay of ^{212}Po. However, for such high energies (above $\sim$ 8 MeV) the dynamic range of the ADC does not allow for the recording of the event. The ADC value is set to zero in such a case. The crosstalk seen in the inner detector can be calulated once the slope of the pick-up is known. This has been measured to be $k_{io} = 0.00375 \pm 0.00004$. Thus only a pick-up event in the inner detector with energies around $0.00375 \times 8800 \sim 33.0$ keV is recorded

whereas no event seems to occur in the outer detector (some energy loss occurs due to the dead layer of the crystals, thus the slightly higher energy value).

After 363 days of pure measuring time the statistics in the inner detector was high enough in order to estimate the background reduction through the anti-coincidence with the outer detector.

Figure 4 shows the low-energy spectrum of the inner detector before and after the anti-coincidence. The cosmogenic X-rays below 11 keV are preserved, since in this case the decays are occurring in the inner detector itself. Also a ^{3}H spectrum with endpoint at 18.6 keV is presumably present. If the anti-coincidence is evaluated in the energy region between 40 keV and 100 keV, the background reduction factor is 4.3. The counting rate after the anti-coincidence in this energy region is 0.07 events/(kg d keV), thus very close to the value measured in the Heidelberg-Moscow experiment with the enriched detector ANG2 [9]. In the energy region between 11 keV and 40 keV the background index is with 0.2 events/(kg d keV) a factor of 3 higher.
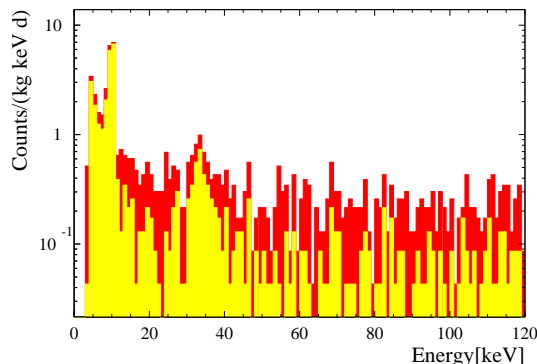

Fig. 4. Low-energy spectrum of the inner detector. The light shaded spectrum corresponds to the events using the anticoincidence, the dark shaded spectrum to all events.

2.2   Dark Matter Limits

The evaluation for dark matter limits on the WIMP-nucleon cross section $\sigma_{\text{scalar}}^{\text{W}-\text{N}}$ follows the conservative assumption that the whole experimental spectrum consists of WIMP events. Consequently, excess events from calculated WIMP spectra above the experimental spectrum in any energy region with a minimum width of the energy resolution of the detector are forbidden (to a given confidence limit).

The parameters used in the calculation of expected WIMP spectra are summarized in [9]. We use formulas given in the extensive review [11] for a truncated

Maxwell velocity distribution in an isothermal WIMP–halo model (truncation at the escape velocity, compare also [12]).

After calculating the WIMP spectrum for a given WIMP mass, the scalar cross section is the only free parameter which is then used to fit the expected to the measured spectrum using a one-parameter maximum-likelihood fit algorithm.

To compute the limit for the HDMS inner detector we took only the last 49 days of measurement. We omit the first 260 days in order to reduce the contaminations due to long-lived cosmogenically produced materials. These have life times of typically ~ 200 days. The energy threshold of the measurement was 2 keV. The resulting preliminary upper limit exclusion plot in the $\sigma_{\mathrm{scalar}}^{\mathrm{W-N}}$ versus M_{WIMP} plane is shown in Fig. 5.

Already at this stage, the limit is competitive with our limit from the Heidelberg-Moscow experiment. In the low mass regime for WIMPs the limit has been improved due to the low-energy threshold of 2 keV reached in this setup.

Also shown in the figure are limits from the Heidelberg-Moscow experiment [9], limits from the DAMA experiment [13] and the most recent results in form of an exclusion curve from the CDMS experiment [14]. The filled contour represents the 2σ evidence region of the DAMA experiment [1].
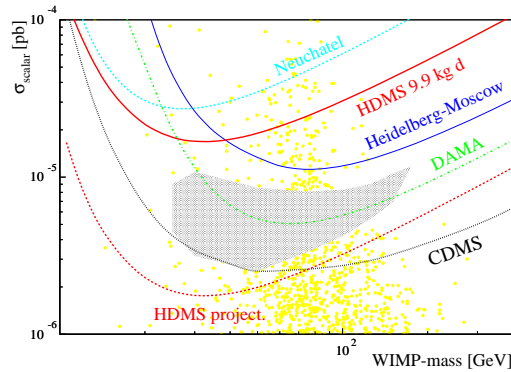

Fig. 5. WIMP-nucleon cross section limits as a function of the WIMP mass for spin-independent interactions. The upper solid line corresponds to the limit set by the HDMS-prototype detector. The plain curves correspond to the limits given by CDMS [14], DAMA [13] and the Heidelberg-Moscow Experiment [9]. The filled contour represents the 2σ evidence region of the DAMA experiment [1]. The lower dashed line shows the expectation for the HDMS final setup assuming a threshold of 2 keV.

2.3 Outlook for the HDMS Experiment

The prototype detector of the HDMS experiment successfully took data at LNGS over a period of about 15 months. All of the background sources were identified.

The background reduction factor in the inner detector through anticoincidence is about 4. It is less then previously expected [4], due to the smaller diameter of the veto detector than originally planned. Nevertheless, the background in the low-energy region of the inner detector (with exception of the region still dominated by cosmogenic activities) is already comparable to the most sensitive dark matter search experiments.

For the final experimental setup, important changes were made.

- The crystal holder was replaced by a holder made of ultra low level copper.
- The soldering of the contacts was avoided, thus no soldering tin was used in the new setup.
- The inner crystal made of natural Germanium in the described prototype was replaced by an enriched ^{73}Ge crystal (enrichment 86 %). In this way, the ^{70}Ge isotope (which is the mother isotope for ^{68}Ge production) is strongly de-enriched (the abundance in natural Germanium is 7.8%).

After a period of test measurements in the low-level laboratory in Heidelberg, the full scale experiment was installed at LNGS in the in August 2000. The projected final sensitivity of the detector can be seen in Fig. 5.

3   The GENIUS experiment

In order to achieve a dramatic step forward regarding background reduction, a new experimental technique is needed.

Lately there have been two promising approaches to reach this goal:

- Application of standard detection techniques while removing all dangerous contaminations from the direct vicinity of the detectors.
- Cryo-detectors have been developed which are able to detect two signals of the WIMP-nuclear recoil phonons and ionization (e.g. the CDMS experiment [2]), or phonons and scintillation (e.g. the CRESST phase 2 experiment [15]) simultaneously. This enables a very effective discrimination between nuclear recoils and electromagnetic interactions.

The GENIUS (GErmanium in liquid NItrogen Underground Setup) proposal uses the first concept [7,8].

3.1   The concept of the GENIUS experiment

The GENIUS project [7,8] is based on the idea to operate 'naked' HPGe crystals directly in liquid nitrogen [16] and to remove all dangerous contaminations from the direct vicinity of the crystals. That Ge detectors really work in liquid nitrogen has been shown in [17,18]. Using a sufficiently large tank of liquid nitrogen, the latter can act simultaneaously as cooling medium and shield against external activities, since it is very clean with respect to radiopurity due to its production history (fractional distillation). The conceptual design of the experiment is depicted in figure 6.
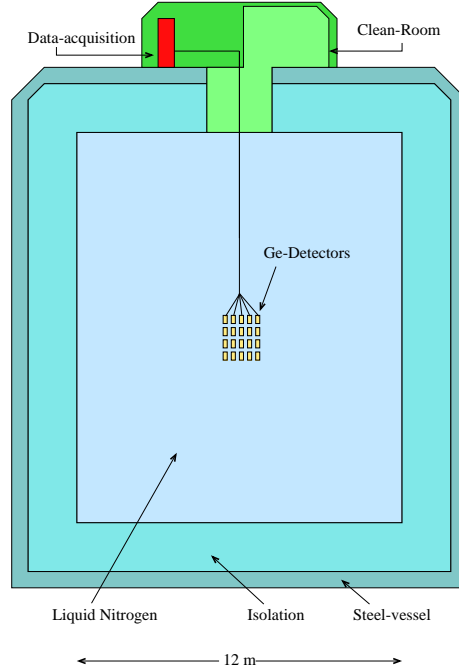
Fig. 6. Schematic view of the GENIUS project. An array of 100 kg of natural HPGe detectors for the WIMP dark matter search (first step) or between 0.1 and 10 tons of enriched ^{76}Ge for the double beta decay search (final setup) is hanging on a support structure in the middle of the tank immersed in liquid nitrogen. The size of the nitrogen shield would be 12 meters in diameter at least. On top of the tank a special low-level clean room and the room for the electronics and data acquisition will be placed.

The proposed detection technique is based on ionization in HPGe detectors. The crystals would be of p-type. p-type detectors have the advantage that the outer contact is n^+ and the surface dead layer therefore several hundred micrometers. This effectively prevents the detection of α- and β particles which would otherwise dominantely contribute to the background. The ideal working temperature of the p-type detectors is 77 K. The cooling of the HPGe crystals is very efficient since the detectors are in direct thermal contact with the cooling medium liquid nitrogen.

It has been shown that according to Monte Carlo simulations with this approach a reduction of background by three to four orders of magnitudes can be achieved [7,8,17,18]. The final reachable background index is estimated to be around $\sim 10^{-2}$ counts/(kg keV y) in the low-energy region below 100 keV relevant for WIMP Dark Matter search. The sensitivity reachable with this background for neutralinos as dark matter can be seen in Fig. 7.
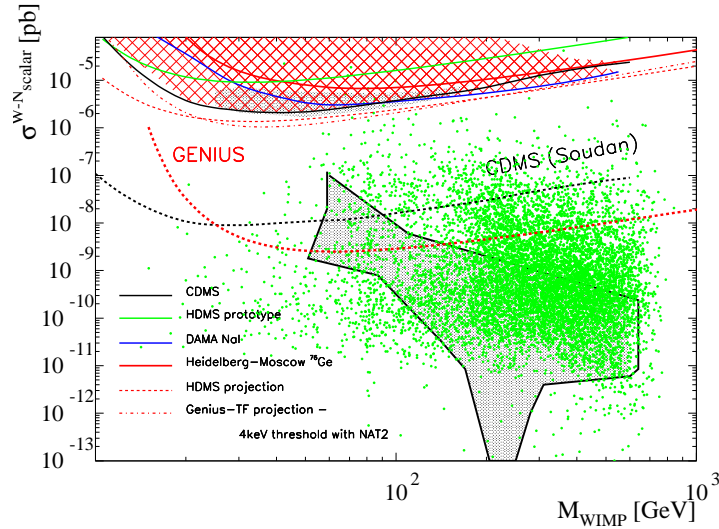
Fig. 7. Exclusion plot of the scalar WIMP-nucleon elastic scattering cross section as a function of the WIMP mass. Plotted are excluded areas from the presently most sensitive direct detection experiments (hatched area, DAMA [13], CDMS [2], Heidelberg-Moscow [9], HDMS prototype[4]) and some projections for experiments running or being presently under construction (HDMS, GENIUS-TF [6]). The extrapolated sensitivities of future experiments (GENIUS [8], CDMS at Soudan [2]) are also shown. The scatter plot corresponds to predictions from theoretical considerations of the MSSM [19]. The small shaded area represents the 2σ evidence region from the DAMA experiment [1]. The large shaded area corresponds to calculations in the mSUGRA-inspired framework of the MSSM, with universality relations for the parameters at GUT scale [20] (Figure taken from [19]).

3.2 Tritium production in HPGe at sea level

As evident from previous considerations of the expected background [8,18], great care has to be taken about the cosmogenic isotopes produced inside the HPGe crystals at sea level. Without additional shield against the hard component of cosmic rays during a fabrication time of ten days many isotopes are produced which significantly reduce the sensitivity of GENIUS as a dark matter detector. Especially the production of ^{68}Ge from the isotope ^{70}Ge affects the sensitivity by increasing the energy threshold of the detector to 12 keV. In the main reaction leading to ^{68}Ge enhancement also tritium is produced through the process ^{70}Ge(n,t)^{68}Ge. Tritium has a half life of 12.35 years and can thus not be deactivated within a reasonable time. ^{3}H is a β emitter with a Q-value of 18.6 keV.

The cosmogenic production rate of ^{3}H in natural germanium has been estimated through simulations in [21,22] using the cosmic neutron fluxes cited in [23,24]. For natural germanium it is estimated to be less than ~ 200 atoms per day and kg material. Using this upper limit for tritium production at sea level

with an overall fabrication time of ten days this would mean a tritium abundance of $\sim$ 2000 atoms per kilogram material. With the half life of 12.3 years this results in a decay rate of $\sim$3.6 μBq/kg equivalent to $\sim$113 decays per year (this is in very good agreement with the result in [25]). Even assuming an energy threshold of 12 keV and taking into account the spectral shape of tritium decay this yields an event rate of approximately 2 counts/(kg keV y) in the energy region between 12 keV and 19 keV, which is by two to three orders of magnitudes above the allowed count rate.

This consideration drastically shows the importance of proper planning of the crystal production and transportation. To avoid major problems with cosmogenic isotopes it is therefore essential to minimize the exposure of the crystals to cosmic rays at sea level.

If it is assumed that during the zone refining process the germanium material is sufficiently shielded against the cosmic radiation, the unshielded time would with $\sim$ 3.5 days be by two orders of magnitudes too long. This exposure at sea level would result in approximately 0.7 counts/(kg keV y). In addition it has to be taken into account that the crystal might have to go through several production steps more then once thus increasing the exposure time by another 16 hours per additional cycle.

It is therefore required to additionally shield the detector material during production and transportation using approximately 2m of heavy concrete. Heavy concrete can be produced with a density up to 5.9 g/cm^3. Thus an additional concrete shield of 1 m could act as a shield of roughly 5 mwe. This reduces the hard nucleonic component mainly responsible for the cosmogenic isotope production by one to two orders of magnitudes [16]. A further increase of shielding strength does not seem to be reasonable since the cosmogenic production through the cosmic fast muons which is by approximately two orders of magnitudes less than through the hadronic component can not be shielded whatsoever.

To make a first approximation of the tritium abundance in the crystals after production and transportation, it is assumed that a shield of 5 mwe can be provided during both fabrication and transport, resulting in a reduction of tritium production by a factor of $\sim$ 30 (see figures 2 and 3 in [16]). The time interval relevant for tritium enhancement starts directly after the zone refining process, since in this step most of the contamination is being removed from the germanium material. Thus for the fabrication (in the ideal case) 78 hours are needed. Without considering transport, this results in approximately 20 tritium atoms per kg detector material. Taking into consideration also a transportation time of one week (shipping), the amount of produced tritium atoms increases to $\sim$70 atoms per kg.

The expected decay rate is $\sim$1.1 per year without and $\sim$3.9 per year with transportation considered. If an energy threshold of 12 keV is assumed for the experiment due to the decay of ^{68}Ge, the events resulting from tritium decay below 12 keV can be neglected. Due to the spectral shape of tritium, every $\sim$10th decay deposits more than 12 keV of energy in the detector. In the energy interval between 12 keV and 19 keV thus 0.11 events per year and 0.39

events per year are expected from tritium without and with transportation considered, respectively. The final background sensitivity would therefore be $\sim 1.6 \times 10^{-2}$ counts/(kg keV y) without additional transportation and $\sim 5.6 \times 10^{-2}$ counts/(kg keV y) with a week of transport from the fabrication site to the site of the experiment. This background level almost corresponds to the curve shown in Fig. 7.

Note that the consideration made here is a very crude approximation. It is, however, possible to say that tritium will definitely limit the sensitivity of GENIUS as a dark matter detector if the germanium crystals are not produced directly underground. Thus it should be seriously considered to produce the detectors underground, directly at the experimental site.

4   The GENIUS-TF

It has been shown in the BARGEIN proposal [26] that with a setup using a conventional shield, a sensitivity can be reached which allows for a test of the DAMA evidence region within a short time period. However, with the BARGEIN setup this test could only be done looking for the expected signal of WIMP dark matter in HPGe detectors: the WIMP-nucleus recoil spectrum. Thus the BARGEIN setup can only verify the CDMS result of (almost) excluding the possibility of WIMP dark matter as favored by the DAMA data [14]. If the active mass of the detector can be increased to approximately 40 kg, as proposed for the GENIUS Test-Facility [5,6], and the background index will be maintained, also the expected signature of WIMP dark matter in form of the annual modulation signal could be tested within a reasonable time window [5,6].

The primary goal of GENIUS-TF is to demonstrate the feasibility of the GENIUS project.

With the GENIUS TF it is planned to test the following points:

Material selections have to be performed for various experimental components like polyethylene and contacting wires, and their purities have to be tested down to 1 event/(kg y keV). A crystal support system, made of low-radioactivity polyethylene has to be developed and designed such that it can be extended in order to house up to 40 crystals (100 kg) and more and later implemented into the GENIUS setup.

Furthermore a new, modular data acquisition system and electronics, capable of taking data from up to 300 and more detectors simultaneously has have to be developed and tested.

From the low-energy spectrum valuable experiences can also be gained about the cosmogenic activation of the HPGe-crystals, since the exposure history of the crystals is monitored in detail during manufacturing and transport. Especially for the ^{3}H contamination it is of utmost importance to have a basic understanding of its production rate for the GENIUS project.

Finally it has to be confirmed that 'naked' Ge detectors work reliably in liquid nitrogen over a longer period of time. In the former studies the HPGe crystals have been operated reliably over typical time periods of weeks; however,

for an experiment of the scale of the GENIUS project, it has to be shown that this is also possible over time scales of years.

Besides above issues, GENIUS-TF will have a physics program of its own, as discussed below.

4.1   The Test Facility

The concept of the GENIUS proposal has the great advantage that no individual cryostat system is needed. Instead the HPGe crystals are surrounded by liquid nitrogen of much higher radiopurity which in addition provides ideal cooling and shielding against external radiation. This opens the new research potentials for the Genius project [7,8,17].

It is proposed to install a setup with up to fourteen detectors on a small scale [5,6] in order to be sensitive in the range of the DAMA result [1] on a short time scale and to prove the long term stability of the new detector concept and some other important aspects for the realization of the GENIUS project discussed above.

The design is shown in figure 8. It is based on a dewar made from low activity polystyrene and on a shield of zone-refined germanium bricks inside the dewar and low-activity lead outside the dewar. A layer of boron-loaded polyethylene plates for suppression of neutron-induced background completes the shield.
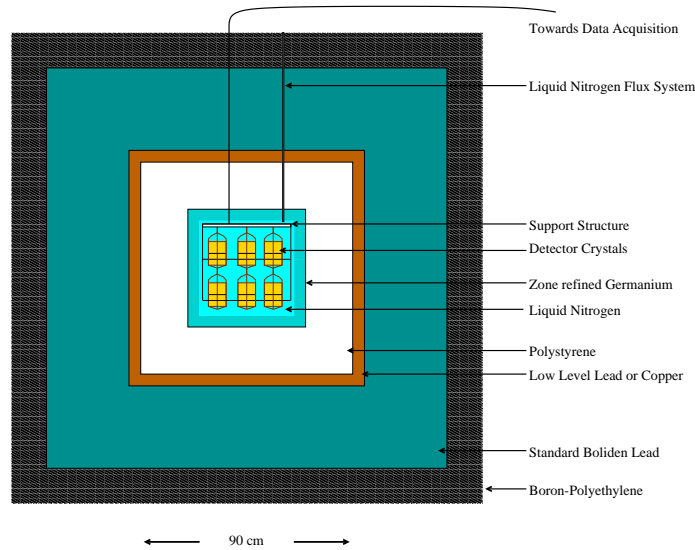

Fig. 8. Conceptual design of the GENIUS-TF. Up to 14 detectors will be housed in the inner detector chamber, filled with liquid nitrogen. As a first shield 5 cm of zone-refined Germanium will be used. Behind the 20 cm of polystyrene isolation another 35 cm of low-level lead and copper and a 15 cm borated polyethylene shield will complete the setup.

330 kg of zone-refined high-purity Germanium bricks would serve as the inner layer to shield the 'naked' HPGe detector against the less radio-pure polystyrene. Also the first 10cm layer outside the polystyrene-dewar needs to be of extreme radiopurity. The same type of copper as installed in the Heidelberg-Moscow experiment, and/or some complementary low-level lead could be used. To shield the external γ rays (natural radioactivity from the surroundings) an overall lead layer of approximately 35 cm is needed.

Using this concept an inner detector chamber of 40 cm×40 cm×40 cm would be sufficient to house up to seven HPGe-detectors in one layer or 14 detectors in two layers. This will allow for the development and test of a holder system for the same amount of crystals.

The overall dimension of the experiment will be 1.9 m×1.9 m×1.9 m (without the boron-loaded polyethylene) thus fitting in one of the buildings of the Heidelberg-Moscow experiment which is used momentarily for material measurements.

The background considerations and simulations discussed in [6,26] suggest that a reduction of the background by a factor of ∼5 with respect to the Heidelberg-Moscow-Experiment can be attained with the proposed setup.

Assuming a final target mass of 40 kg, an energy threshold of 12 keV and a background index of 4 counts/(kg keV y) corresponding to ∼ 0.01 counts/(kg keV d) in the energy region between 12 keV and 100 keV the GENIUS-TF would need a significance of 190 kg y to see the claimed DAMA annual modulation with 95% probability and 90%C.L. (see [27]). This corresponds to an overall measuring time of approximately five years which would correspond to the life time of this experiment.

However, the new detectors will have an energy threshold of 0.5 keV (four detectors have already been produced by the end of February 2001) thus allowing for the use of the experimental spectrum in the energy range between the threshold and the X-ray peaks seen from the cosmogenically produced isotopes. This could significantly improve the sensitivity of the GENIUS-TF on the annual modulation effect.

4.2   Installation of the GENIUS-TF and time schedule

With the dimensions for the inner detector chamber given above, the materials shown in table 1 will be needed for the installation of the GENIUS-TF.

The Heidelberg-Moscow-Collaboration possesses ∼ 330 kg of zone refined Germanium bricks, ∼ 10 tons of Boliden-lead and ∼ 500 kg ancient low-level lead. These materials can be installed in the GENIUS-TF without additional costs.

The BOREXINO collaboration is running a liquid nitrogen filtering device in the Gran Sasso underground laboratory. The capacity of this machine is by far not used by the needs of the BOREXINO collaboration. Thus this device could also serve as the low-level nitrogen support for the GENIUS-TF. Once a week two hundred liters of low-level nitrogen dewars could be filled from the filtering

Material	Amount
14 HPGe-detectors	$\sim$ 40 kg
Electronics	—
Germanium bricks[2]	$\sim$ 330 kg
Polystyrene box	$\sim$ 40 kg
Low-Level Lead (LC2 or ancient) or	3076 kg
Low-Level Copper	$\sim$ 7 t
Boliden Lead bricks	$\sim$ 30 t
Nitrogen filling and	3-4 100 liter low
cleaning device	level dewars

Table 1. Amount of materials needed for the installation of the GENIUS-TF.

device and stored for deactivation of ^{222}Rn for one week. This amount of liquid nitrogen would be enough for approximately one week.

The development of the liquid nitrogen cleaning and filling device will be started soon in collaboration with the BOREXINO experiment. The construction of the setup can be started immediately since no additional space in the Gran Sasso Underground Laboratory is required. The data acquisition system of the HDMS experiment can be used to obtain first data with two detectors which are already housed in the Gran Sasso Underground Laboratory. The first results can be expected in the end of the year 2002 already.

5   Conclusions

We presented first results of a 15 month measuring period with the prototype HDMS detector. The obtained sensitivity is already now comparable to the most sensitive dark matter search experiments. The final setup has been installed in August 2000 in the Gran Sasso Underground Laboratory. Several improvements have been achieved for the final detector: The crystal holder system was replaced with a low-level copper holder system and soldering of the contacts was avoided. Furthermore the inner detector consists of enriched ^{73}Ge, thus strongly suppressing the ^{68}Ge contamination with respect to the prototype detector, substantially lowering the energy threshold. The expected sensitivity of the HDMS experiment will allow to test by exclusion plot the DAMA evidence region from the annual modulation signature [1].

We proposed the GENIUS-TF, a new experimental setup which has been approved. We showed, using detailed Monte Carlo simulations that the GENIUS-TF could reach a background of $\sim$ 4 counts/(kg keV y) in the energy region between 12 keV and 100 keV. Thus it could for the first time probe the DAMA evidence region using both, the WIMP-nuclear recoil signal and the annual modulation signature. The GENIUS-TF is planned as a test setup for the GENIUS project and will be installed in 2001.

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[2] Property of the Heidelberg-Moscow-Collaboration

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